

Pulsed Lidar Measurements of Atmospheric CO₂ Column Absorption in the ASCENDS 2011 Airborne Campaign

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Abstract:

We have previously demonstrated an efficient pulsed, wavelength-resolved IPDA lidar technique for measuring the tropospheric CO₂ concentrations as a candidate for NASA's ASCENDS mission. Our team participated in the 2010 ASCENDS airborne campaigns we flew airborne version of the CO₂ and O₂ lidar on the NASA DC-8. The CO₂ lidar measures the atmospheric backscatter profiles and shape of the 1572.33 nm absorption line using 250 mW average laser power, 30 wavelength samples per scan and 300 scans per second. Most flights had 5-6 altitude steps to > 12 km, and clear CO₂ line shapes were observed at all altitudes. Our post-flight analysis estimated the lidar range and pulse energies at each wavelength every second. We then solved for the best-fit CO₂ absorption line shape, and calculated the Differential Optical Depth (DOD) at the line peak. We compared these to CO₂ DODs calculated from spectroscopy based on HITRAN 2008 and the conditions from airborne in-situ readings. Analysis of the 2010 measurements over the Pacific Ocean and Lamont OK shows the expected ~linear change of the peak DOD with altitude. For measurements at altitudes > 6 km the random errors were ~ 0.3 ppm for 80 sec averaging times. After the 2010 flights we improved the airborne lidar's scan uniformity, calibration and receiver sensitivity.

Our team participated in the seven ASCENDS science flights during late July and August 2011. These flights were made over a wide variety of surface and cloud conditions near the US, including over the central valley of California, over several mountain ranges, over both broken and solid stratus cloud deck over the Pacific Ocean, snow patches on mountain tops, over thin and broken clouds above the US Southwest and Iowa, and over forests near the WLEF tower in Wisconsin. Analyses show the retrievals of lidar range and CO₂ column absorption, as well as estimates of CO₂ mixing ratio worked well when measuring over topography with rapidly changing height and reflectivity, through thin clouds and to stratus cloud tops. For regions where the CO₂ concentration was relatively constant, the measured CO₂ absorption profile (averaged for 50 sec) matched the predicted profile to better than 1% RMS error for all flight altitudes. For 1 & 10 second averaging, the scatter in the retrievals was limited by signal shot noise (i.e. the signal photon count). Analysis to date shows the decrease in CO₂ due to vegetation when flying easterward over the Great Plains as well as the increase in CO₂ concentration in the vicinity of the coal-fired power plant in New Mexico. Examples of these and other results will be presented.